Small-scale farmers and their local maize varieties in Santa Catarina

The agricultural sector in the state of Santa Catarina in southern Brazil is characterized by small-scale farming, with an average farm size of about 20 hectares. Farmers face a number of problems, including changes in rainfall patterns, frequent droughts, low soil fertility, acidic soils, and outbreaks of pests and diseases. These variations in biotic and abiotic stress factors limit crop production and productivity in the small-scale farming sector. Maize is a very important crop as it is associated with the poultry and pork processing industry, which dominates the local rural economy (Ogliari and Alves, 2007). Less significant in size, but no less important, is the amount of maize consumed domestically, in the form of food for the household, animal feed and artisan wares (for example, hats and purses) that are made with maize straw and grains. About 90% of maize produced is used within the farm (Vogt, 2005).

Autonomy in seed production and the use of maize varieties

The municipality of Anchieta is located in the western part of Santa Catarina. Social movements, such as the Small-scale Farmers’ Movement (MPA) and the Women Farmers’ Movement (MHC), as well as the non-governmental organization Support Centre for Small-scale Farmers (CAPA) and the Small-Scale Farmers’ Trade Union (SINTRAF), are critical of the industrial agricultural model as supported by agricultural research and extension services. In order to turn this criticism into practical action, these organizations are aiming to enhance agro-ecology, the farmers’ autonomy in maize seed production and their capacity to maintain local maize varieties. A community-based organization, the Association of Local Maize Variety Farmers and Processors (ASSO), supported by SINTRAF, has been promoting the use of local or crioulo (creole) maize varieties (Ogliari and Alves, 2007). Milho crioulo is the term used by farmers for maize varieties that are maintained and multiplied by small-scale farmers, independently of their origin and cultivation period on-farm. They include local varieties, local composite populations, and seed derived from old, important, improved cultivars. In the late 1990s, crioulo maize varieties became a symbol for agro-ecology, autonomy and self-reliance.
NEABio's involvement in research and development

The activities of farmers' organizations in Anchieta attracted the attention of the Nucleus for Agrobiodiversity Studies (NEABio), which was formed by a group of professors and students of the Federal University of Santa Catarina (UFSC) in 2002. NEABio has been working on several research projects with farmers' organizations in support of crop improvement and on-farm management of maize and other crops. Over the years, an informal partnership has been developed for investigating and supporting on-farm management and the conservation and use of crioulo varieties, using maize as a model for other crops and other municipalities.

Motivation for the participatory genetic enhancement of a crioulo maize variety

Although numerous hybrid maize varieties with high yield potential are available in the market, small-scale farmers in the western part of Santa Catarina are reluctant to purchase and use them. Such varieties have specific requirements, such as the use of fertilizers and pesticides, and need efficient machinery and equipment, in order to explore their high genetic potential. The high cost of seed of hybrid maize varieties has been another limitation. The limited adaptation of the maize hybrids to their production system, in addition to the aforementioned economic reasons, motivated some small-scale farmers, after years of using hybrid maize, to return to open-pollinated local varieties. Open-pollinated local maize varieties (milho crioulo) are an interesting alternative for these farmers, as they require fewer external inputs. The varieties are also less vulnerable to biotic and abiotic stress factors compared to hybrid cultivars (Ogliari and Alves, 2007). In this context, NEABio began to carry out research in 2003, looking at the yield potential and other specific characteristics of these crioulo maize varieties. Together, we explored ways of how we could genetically enhance the performance of these varieties, using a collaborative approach, with the aim of strengthening the autonomy of the farming community in managing and using maize varieties.

Supported farmer breeding of MPA1

Before NEABio began its participatory plant breeding activities in Anchieta, farmers were already involved in farmer breeding, with the support of local organizations. The variety that we worked with in the participatory genetic enhancement process is the product of scientific farmer breeding. The development of MPA1 was initiated by a local farmer, Névio Alceu Folgiarini, with technical support from SINTRAF. The first step in its formation was the inter-crossing of 25 varieties, represented by 18 advanced generations of commercial hybrids; four local varieties, maintained by small-scale farmers at Anchieta; and three varieties derived from selection, which was carried out by local farmers from within the crioulo variety group referred to as Pixurum. In order to assemble the base composite, a sample of 50 ears (300 kernels per ear) was taken from each parental variety. In the following season, five other local varieties of unknown origin were incorporated into the base composite. These five additional varieties were recombined with the first 25 varieties over 1999 and
2000, using the ‘topcross’ procedure. Three cycles of stratified mass selection were applied to establish the population. The farmers that had been engaged in the process decided to name the variety MPA1, in honour of the social movement that supported and inspired them in their work.

Participatory genetic enhancement of MPA1

**Step 1: On-station and on-farm evaluation of crioulo maize varieties**

Since many agricultural communities maintain maize varieties on-farm, the first step in our research was to assess their yield potential. In 2002/2003, we evaluated 23 varieties at the research station of the Santa Catarina State Enterprise for Agricultural Research and Rural Extension (Epargri), in Canoinhas. The results showed a variation in grain yield for the crioulo varieties, with the variety that is referred to as MPA1 showing the best performance. In a subsequent year, we carried out an evaluation at the same station, separating varieties with a plant height above 3.0 m. These taller varieties showed a grain yield of between 2.1 and 7.2 tonnes per hectare (t/ha); the shorter varieties (less than 3.0 m) had grain yields of between 5.1 and 8.0 t/ha. Again, MPA1 proved to be outstanding. What we considered important was the fact that when compared with the average maize yield in Santa Catarina over the two respective years, the crioulo varieties turned out to be producing, on average, significantly more (62% and 59%). Table 5.7.1 shows the results of the on-station evaluation of the varieties.

In consecutive years, further participatory varietal selection was carried out on-farm, by evaluating crioulo maize varieties using different experimental designs (Canci, 2006; Kist, 2006). In subsequent research, the superior performance of MPA1 was confirmed when it was compared to improved and other crioulo varieties for agronomic traits (Kist et al., 2010). MPA1 also showed superior values for kernel nutritional content (Kuhnen et al., 2011), and for resistance to Exserohilum turcicum. At the request of farmers associated with ASSO and SINTRAF, we started a process of participatory genetic enhancement (PGE) of MPA1 in 2003, as illustrated in Figure 5.7.1.

**Step 2: Stratified mass selection of MPA1**

We continued the PGE programme using a modified convergent–divergent scheme, since it caters well with the demands of improving an open-pollinated variety for sustainable agriculture (Kist et al., 2010). In this design, half-sib selections are tested under low-input farm crop conditions (i.e. in varying rather than uniform testing environments). Initially, we used MPA1 that had originated from the farmer Névio Alceu Folgiarini, over three cycles of stratified mass selection, applying a defined set of criteria during pre- and post-harvest selection.

**Step 3: Selection of MPA1 half-sib families**

Adriano Canci and Névio Alceu Folgiarini took a sample of 220 ears from the population in an isolated block, located in a uniform field, based on visual selection in the
field. After harvesting, the sample was evaluated at UFSC for several post-harvest traits and we took 186 ears to represent half-sib families.

**Step 4: Evaluation and selection of half-sib families**

The 186 half-sib families were divided into three experiments, with 62 families in each (three independent samples of half-sib families) plus two checks (the original MPA1 and a recommended, improved open-pollinated variety). We conducted the experiments in three farms, using an $8 \times 8$ partially balanced triple lattice design (including three replications). Each plot consisted of one row, 5.0 m long with 1.0 m between rows. We evaluated the half-sib families for grain yield and plant height and analysed the data according to a completely randomized block design. Kist _et al._
The participatory genetic enhancement of maize in Brazil (2010) further elaborate on the scientific evidence for the effectiveness of the selection for grain yield and plant height in this selection scheme. Those selected half-sib families that resulted in a decrease in plant height of 5.4% in the three experiments (with 25% selection intensity) did not completely correspond to those outstanding families that had resulted in an increase in grain productivity of around 5%, compared to the average of the original base population. To achieve a positive correlation between yield and plant height, simultaneous selection for both traits should be weighed adequately.

We further selected samples of all superior half-sib families, uniform in size, for the recombination block that associated high grain productivity with low plant height. In this way, we were able to genetically enhance MPA1 for the traits that were preferred

Figure 5.7.1 Convergent–divergent selection scheme used for participatory genetic enhancement of MPA1, Anchieta, SC, Brazil. P1 to P30 are 30 sub-populations of MPA1 (C0), used for the formation of the composite population (convergent); 62 half-sib families (divergent) were evaluated in different environments (E1: São Domingos, E2: São Roque, and E3: Café Filho); C1 is the result of recombination in an isolated block (convergent), represented by samples of constant size of the selected families.

Source: Kist et al. (2010).
by small-scale farmers in Anchieta and its surrounding area. Kist et al. (2010) argue that the gain is small when compared with other experiments and selection schemes, but we draw attention to the fact that the current selection was conducted in farms, in contrast to the common experience of plant breeders, who work in experimental farms. Farm-level selection environmental variation takes its share in selection efficiency for such quantitative traits.

**Step 5: Recombination of the selected half-sib families and final selection**

Selected half-sib families were cultivated in a recombination field, in which we included mild selection for traits other than those for yield and plant height. In this selection, we had to be careful since changes in one character can result in other (non-desired) changes in correlated traits (Kist et al., 2010). Over several subsequent cycles, the newly composed, genetically enhanced MPA1 was further improved in farmers’ fields in various locations in the region, and we consolidated the variety as enhanced MPA1. It is currently being prepared for return to the farmers. We have been supported in this process by the same organizations in Anchieta, by Epagri in the municipality of Guaraciaba, by new local government partners in the municipality of Novo Horizonte, and by small farmers’ groups from four municipalities in the western part of Santa Catarina.

**Step 6: Seed production and maintenance of enhanced MPA1**

In the current and concluding phase, seed production and supply, and the maintenance of genetic seed of enhanced MPA1 are our challenges. We need to develop and institutionalize collaboration between researchers and small-scale farmers. In this respect, we must be careful to prevent any contamination from migrant pollen, seed mixing, mutations and seed-borne diseases, which would result in the loss of the genetic gain achieved by the enhanced MPA1.

**Crioulo maize and genetically modified maize varieties: posing new challenges**

An important challenge that we currently face in working with milho crioulo is posed by the genetically modified maize varieties that are currently being introduced. NEA-Bio and partners in the area are engaged in a project to design a strategy to avoid the contamination of crioulo maize varieties. In 2007, the Brazilian Biosafety Commission fixed the minimal distance between genetically modified and non-genetically modified maize fields to 100 m to ensure there is no contamination or transgression. In contrast, the Ministry of Agriculture recommends between 200 and 400 m as the minimum distance of isolation for maize seed production fields. Contamination would be dramatic in the western part of Santa Catarina because small-scale farmers use and maintain many crioulo varieties. Here, the isolation of maize fields is neither a common nor viable practice, which is mainly due to topography or the density of farms. Avoiding gene flow between neighbours’ fields seems almost impossible
(Cordeiro et al., 2008). In this respect, NEABio is currently paying more attention to the participatory mapping of areas with a high density of milho crioulo. We aim to identify safe areas for the conservation of milho crioulo, and promote seed saving and organic maize production. The collaboration of NEABio with its partners has evolved from building the scientific basis for accepting the adaptation potential of crioulo varieties, to developing and adapting a breeding methodology aimed at the genetic enhancement of MPA1. At present, our partnership aims to strengthen and support farming communities in maintaining their crioulo varieties in times of advanced introduction of genetically modified maize.